Electromagnetic Characterization of the LWA1 Antenna Array

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The LWA1 radio telescope is an array of 258 dual-polarized broadband dipole-like antenna elements, collocated with the VLA in Central New Mexico, operating in the 10–88 MHz range (Ellingson *et al.* (2012), arXiv:1204.4816 [astro-ph.IM]). The antennas are pseudo-randomly distributed with minimum spacing of 5.4 m (0.18λ and 1.58λ at 10 MHz and 88 MHz respectively) over a 110 m $\times$ 100 m elliptical aperture which is only partially covered by conducting ground screen material. The large number of complex antennas, varying electrical separation between antennas with frequency, and interaction with the electromagnetically-complex ground makes the array quite difficult to analyze. In particular, mutual coupling among array elements is not safely ignored. Furthermore, the sensitivity of LWA1 is strongly limited by Galactic noise as opposed to receiver self-noise. Because Galactic noise is correlated between closely-spaced antennas, combining N antennas typically provides less than factor-of-N improvement in beam sensitivity unless countermeasures are taken in beamforming.

In this presentation we shall review the design of the array and our most recent attempts to develop an electromagnetic model for the array that accounts for these issues, already summarized to some extent in Ellingson (2011), *IEEE Trans. Ant. & Prop.*, 59, 1855. We shall also summarize recent work attempting to precisely characterize the LWA1 antenna array using astronomical measurements, and thereby validate our electromagnetic model. These measurements are facilitated by the design of the LWA1 signal processing system, in which each antenna is digitized separately and all subsequent processing – including beamforming – is done digitally. In particular, LWA1 provides two "all dipoles" modes which allow coherent acquisition of the signals from all dipoles simultaneously. These modes make it possible to study in detail the relationship between the behavior of individual antennas and the resulting beams and images. In this presentation we will describe the use of the LWA1's digital processing modes to obtain precise measurements of the responses of both beams and individual antennas using only astronomical sources. These results will then be compared to the results obtained from our electromagnetic model.

Finally, we will offer some lessons learned that might be applied in the design of proposed future large arrays of closely-spaced antennas operating at frequencies below $\sim$ 400 MHz where sensitivity is potentially Galactic noise-limited.